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SOME PHASES OF PROTEIN CATABOLISM AND FATIGUE.

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The work of many observers, notably that of Luciani and of Benedict and Cathcart, has shown conclusively that normally very little protein is utilized as a source of energy. Most investigators agree that muscular work is not accompanied by an increased nitrogen excretion, although there may be a marked increase some hours later. Garratt found that the maximum occurred about 12 hours after the cessation of work, and Tissie found a high excretion during the following day. This is in agreement with the lag of 24 hours reported by Atwater, Woods, and Benedict. Although it is probably true that the proteins of the cells do not commonly serve as a primary source of energy, they are nevertheless a part of the working machine, and, as such, are subject to the wear and tear experienced by the machine. It is then not surprising that to a certain extent protein catabolism is involved in muscular effort.

One may take, however, an entirely different point of view. Many of the amino-acids comprising the protein molecule are complex in structure and composition. Some of them are of interest because of the ease with which certain of their components enter into reactions involving the transfer of oxygen. Such components or side chains may reasonably be thought of as being intimately and fundamentally bound up with cellular respiration. This is particularly true of the sulphur bearing amino-acids, as has been pointed out by Mathews.

Assuming that the sulphur moiety of an amino-acid is involved in cellular respiration, one might expect an increased sulphur output, probably in the oxidized state, concomitant with any augmentation in the rate of cellular respiration. This would not necessarily involve an immediate disruption of the remainder of the protein molecule and the consequent release of nitrogen. Some time after increased demands have ceased to be made upon the cell, possibly not until a succeeding period of sleep, it is conceivable that the impaired respiratory mechanism might be restored to its normal condition by replacing the desulphurized portion of the molecule with amino-acids of the necessary composition or structure. Such amino-acids as have given up their sulphur would be of no further service for this purpose and would therefore be de-aminized, utilized as a source of energy, and excreted simply as an exogenous oversupply of these acids. This provides a plausible explanation of the delayed nitrogen excretion which follows work, as was noted above, and forms the theoretical basis of the present research.

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[1] Analyses made prior to Nov. 1, 1917, were done by E. C. Britton, Scientific Assistant, United States Public Health Service.

Practically, our immediate purpose in undertaking this problem was to determine a change in the chemical composition of the urine, which could be used as an index of fatigue in industrial workers. In view of the fact that our observations were necessarily made on factory employees engaged in their usual occupations and mode of living, it was impossible to regulate or secure accurate knowledge of the diets of our subjects. For this reason a large number of workingmen were studied in order that an approximation of the conditions existing in the average individual might be obtained. As a point of comparison we performed a similar series of determinations on men who were recovering from noncomplicated hernia operations, but who were still confined to their beds in the hospital. These, we believed, were the most readily accessible resting subjects from whom we could obtain the necessary control data.

Another element of inaccuracy was introduced by the manner in which we were obliged to obtain our specimens of urine. Because of the conditions under which these observations were made, we were unable either to obtain 24-hour samples for analysis or to know the length of the period of excretion which each specimen represented. In order to obtain a basis for comparing analyses, the following routine procedure was carried out. A morning sample was obtained shortly after the subject had reached his post for work. This represented the second voiding of the day, inasmuch as he had been instructed to empty the bladder immediately upon rising. An afternoon sample was procured shortly before work stopped for the day. The same relations were observed when hospital patients were the subjects as when the subjects were factory employees.

Part I. Sulphurs.

Determinations of the total sulphur and total sulphates were made from the point of view just outlined. Total and free phenols and ethereal sulphates were also estimated on the same specimens; but since the purpose of these latter analyses was essentially different from that of the former, they will be described in a separate section. Naturally, the concentration of the urines tended to be greater in the afternoon than in the morning, as indicated by specific gravity determinations, so that expressing our results as grams per 100 c. c. would merely illustrate the greater evaporation of water from the skin or lungs during work. Because of the fact previously referred to, that the proteins are not essentially involved in the production of energy, and since the total nitrogen of the urine is a rough index of protein metabolism, this constituent was determined simultaneously with those already mentioned and all data were converted into parts per gram of nitrogen in order to permit a comparison of the results obtained from different specimens. The total sulphur was determined by Benedict's method, using Denis' sulphur reagent. Folin's technique was employed in estimating the total and ethereal sulphates. The total nitrogen was determined by the Kjeldahl method with copper sulphate as the catalyzer.

DISCUSSION OF RESULTS.

Those portions of the data in the extended tables at the end of the paper which are of interest for our present purpose are the morning and evening ratios of total sulphur and sulphates and the variations in the percentage of total sulphur which occurs in the oxidized state.

TABLE I.—*Morning and afternoon ratios of total sulphur and sulphate per gram of nitrogen in the urine of the controls and the entire group of workingmen.*

Occupation.	Number of subjects.	Number of experiments.	Total sulphur ÷ total nitrogen × 1,000.			Total sulphate ÷ total nitrogen × 1,000.			Total sulphate ÷ total sulphur × 100.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
Rest	15	30	80	87	109	69	69	100	86	79	92
Work	27	80	75	90	120	61	77	126	81	85	105

In Table I our experimental results, so expressed, have been summarized for the control series and for the entire group of workingmen. From this table it will be seen that the total sulphur per gram of nitrogen excreted in the afternoon was greater than that excreted in the morning in the case of both sets of men. We have interpreted this increase as resulting primarily from the ingestion of food. It is possible that the increased rate of metabolism, which was naturally present, even in the controls, was a contributing cause of this increase, though of considerably less importance than the character of the diet. Such an increase may be presumed from the diurnal temperature curve and from the slightly greater activity during the waking period.

Contrasted with the total sulphur, we find that whereas the output of total sulphate per gram of nitrogen remained practically the same in the afternoon as it was in the morning in the case of the controls, there was an increase of 26 per cent in the case of the active men. This increase, we believe, should be largely, if not wholly, attributed to the augmented cellular activity associated with increased muscular work. Correlated with the two points just noted, we find that there was a smaller proportion of the total sulphur excreted as sulphates in the afternoon than in the morning by the resting men, while the reverse is true of those who were active.

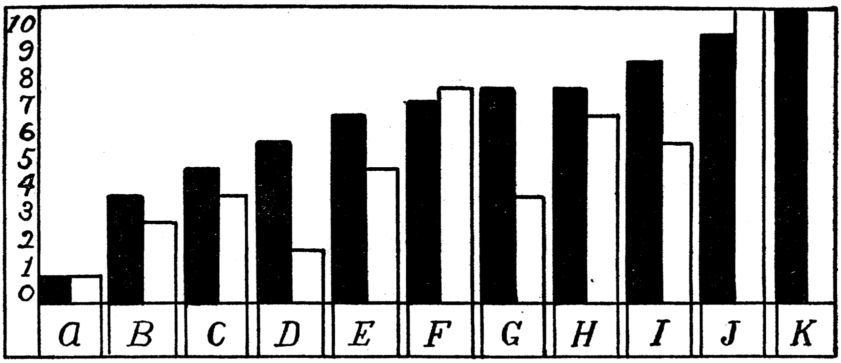

FIG. 1.—Comparison of the arduousness of occupations as estimated by four observers and as indicated by total sulphate excretion, the former being represented by solid columns and the latter by outline. A=rest; B=laboratory work; C=laboratory work and 10-mile walk; D=brazing; E=cyanide furnace; F=drop forge; G=5-pound hammer work; H=25-pound sledge work; I=ramming cores; J=excavating; K=running a 12-mile Marathon race.

In order to carry the analysis further, four men familiar with the various occupations were asked to arrange them in a list in the order of their arduousness. The values given to each occupation in the several lists were then averaged and a final list was made in which the severity of the work increased progressively from resting in bed to running a 12-mile race. In Figure 1 this arbitrary estimate of the degree of arduousness of the various occupations has been compared with a grouping derived from the morning-evening sulphate ratios. When the operations were arranged in this manner the order did not differ from that of any of the four lists more than they differed among themselves; and it will be seen that with two or possibly three exceptions there were no striking differences between the order indicated by the experiment and that arrived at by other means of estimation. The sulphate ratios from which this figure was prepared are given in column 9 of Table II.

Table II.—*Morning and afternoon ratios of total sulphur and sulphate per gram of nitrogen in the urine of the controls and the group of workingmen arranged in order of the arduousness of their work.*

Occupation.	Number of subjects.	Number of experiments.	Total sulphur÷total nitrogen×1,000.			Total sulphate÷total nitrogen×1,000.			Total sulphate÷total sulphur×100.		
			a.m.	*p.m.*	*p.m./a.m.*	*a.m.*	*p.m.*	*p.m./a.m.*	*a.m.*	*p.m.*	*p.m./a.m.*
Rest	15	30	80	87	109	69	69	100	86	79	92
Brazing	1	4	87	98	113	75	87	116	87	88	102
Laboratory work	4	9	73	85	116	70	81	116	96	96	100
Laboratory work +walking	2	2	68	77	113	56	69	123	83	90	108
Using 5-pound hammer	2	10	80	99	124	67	83	124	84	85	101
General factory work	5	7	70	85	121	57	73	128	81	86	106
At cyanide furnace	2	8	77	95	123	63	82	130	82	86	105
Ramming cores	3	13	63	80	127	51	68	133	81	85	105
Using 25-pound sledge	1	5	64	81	127	49	68	139	76	84	111
Drop forge	1	2	76	108	142	58	90	155	77	83	108
Excavating	1	6	56	92	164	46	82	179	82	88	107
Running 12 miles	3	3	96	161	168	64	130	204	66	81	123

Column 6 of the same table shows that there was a tendency for the total sulphur to increase in the same manner, but here we find a rather striking exception in the case of the bed patients. A comparison of column 6 with the last column of this table shows, however, that in most cases, especially in occupations involving heavy work, there was not only an increase in total sulphur but a relative increase in the oxidized sulphur. Here again the inactive men were an exception to the rule, as there occurs in their case a relative fall of 8 per cent in the oxidized sulphur. This is in accord with our conception of the changes in the sulphur metabolism. The increase in total sulphur we attribute largely to the ingestion of food. The majority of the men in the hospital chosen for this study were on an ordinary mixed diet, well balanced and adequate in quantity. Hence their increase in total sulphur comparable, in magnitude, to that of the average man, is not to be regarded as unexpected. The unchanged total sulphate excretion indicates that in contrast with the working men the energy demand of the organism and its cellular respiration was not sufficiently augmented to involve the increased supply of sulphur with its subsequent oxidation.

TABLE III.—*Morning and afternoon ratios, by days, of total sulphur and sulphate per gram of nitrogen in the urine of core rammers.*

Subject.	Date of observation.	Total sulphur÷total nitrogen×1,000.			Total sulphate÷total nitrogen×1,000.			Total sulphate÷total sulphur×100.		
	1917.	*a. m.*	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
R_1	Nov. 5	65	91	140	54	78	144	83	85	103
	Nov. 6	52	82	158	41	72	176	80	87	109
	Nov. 7	62	79	128	53	69	130	86	88	102
	Nov. 8	61	69	113	53	62	117	86	90	105
	Average	60	80	133	50	70	140	84	87	104
R_2	Nov. 15	63	84	133	49	72	147	78	86	110
	Nov. 16	62	79	127	51	65	127	81	82	101
	Nov. 17	73	69	94	43	54	125	59	78	132
	Nov. 19	83	86	104	67	70	104	80	81	101
	Nov. 20	77	88	114	69	73	106	89	83	93
	Nov. 21	61	82	135	50	74	148	82	89	109
	Nov. 22	60	71	118	50	60	120	83	84	101
	Average	68	80	118	54	67	124	79	84	106

In Table III will be found the data of two core rammers, given by days. A study of column 8 will reveal the fact that though there was a qualitative agreement from day to day and from man to man, there was at the same time considerable individual and daily variation. Thus, R_1 showed a general tendency to run higher in sulphur and sulphate ratios than R_2, and had he alone been studied, the rammers would have been placed between the heavy sledge and drop-forge men, which would have been in almost complete agreement with the list prepared by the four observers. R_2 not only ran much lower but showed more daily variations than R_1. This we believe does not invalidate the scheme suggested for determining the arduousness of an operation, but merely shows the necessity of making a large number of observations on a considerable number of men.

In 1900 Sherman and Hawk published a paper giving data from which their sulphate excretion per gram of nitrogen could be calculated. They also gave in detail their habits of life during the experiment, and the character and amount of the food consumed. When the morning and evening output of sulphate sulphur is compared as in our experiments, we find that at 6.30 p. m. there was a rise of 16 per cent of sulphur per gram of nitrogen above that present at 9.30 a. m. They were at the time working in the laboratory. It is significant that this value is the same as that obtained for the laboratory workers in our own series.

They also gave figures from which the rate of sulphur excretion may be calculated. This has been done for the average of the data obtained on five normal days for both men, and the result is shown in Figure 2.

It will be seen from this figure that there was practically no rise in the first three hours after breakfast, but that there was a marked rise after lunch, followed by a still greater one after dinner. This they interpreted as due to the cumulative effect of the ingested sulphur, and a comparison with the curves obtained after high protein feeding would indicate that no doubt this is a factor. May not the effect of work be a factor as well, however? On this hypothesis the six-hour lag would represent the lag which would necessarily occur between the freeing of the sulphur from the protein molecule and its excretion, that is, the time necessary for initial metabolism, complete oxidation, and excretion.

This figure also shows that the S/N curve is roughly parallel to the curve showing the rate of sulphur excretion. Therefore, although S/N values may not be replaced by those denoting the rate of sulphur excretion, a general qualitative correspondence exists between them and permits one to get some idea of the rate of sulphur elimination even though the exact period of excretion is unknown.

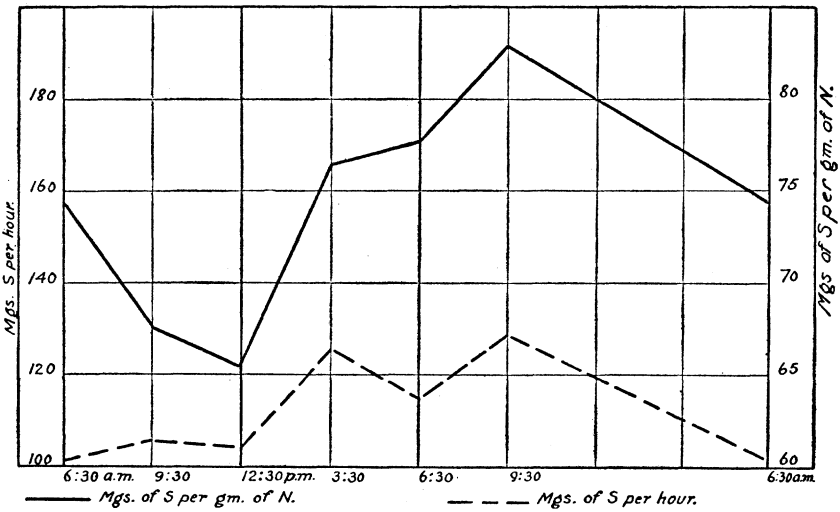

FIG. 2.—Sulphate excretion per gram of nitrogen and rate of sulphur excretion per hour, computed from data obtained by Sherman and Hawk.

Part II. Phenols.

Because of the different point of view which has been assumed in the study of the phenols, it was thought advisable to discuss the results upon phenols independently, although they were obtained upon the same subjects and from the same specimens of urine as those reported in the previous section.

Lee has obtained fatigue effects on excised muscle with indol and skatol which were analogous to those obtained with lactic acid, the classic example of the so-called fatigue substances. In the human organism, indol and skatol, together with phenol and the cresols, arise from bacterial activity in the intestine and are absorbed. Their toxicity in the free state when they are in sufficient concentration is not doubted. That the organism reduces their toxicity by conjugation with sulphuric and glucuronic acids has been established by Baumann and later workers in this field. Folin has shown within recent years that, contrary to the general supposition, the phenols are by no means excreted quantitatively in the conjugated state. Whether or not the ability of the organism to conjugate these toxic substances is altered by muscular effort, therefore, was thought worthy of investigation.

As previously mentioned, the following analyses were made on the urine collected as described in the foregoing section: free and total phenols, ethereal sulphates, and total nitrogen. The phenols were determined by the method of Folin and Denis. The methods involved in the other analyses have been described. As in presenting the results of our sulphur analyses, the concentrations of total and conjugated phenols have been divided by the concentration of total nitrogen. This may not be strictly justifiable, for, as Moore has stated, trebling the protein intake doubles the phenol excretion; but in view of the fact that 24-hour specimens of urine were not available, and that it was not known how long a period each sample of urine represented, this was the most practical means which occurred to the authors of making afternoon and morning samples comparable. It should be pointed out, moreover, that our conclusions are drawn from relative and not absolute values.

DISCUSSION OF RESULTS.

TABLE IV.—*Morning and afternoon ratios of phenol and sulphate per gram of nitrogen in the urine of controls and the entire group of workingmen, prepared from the average of all determinations.*

Occupation.	Number of subjects.	Number of experiments.	Total phenol÷N×1,000.			Free phenol÷N×1,000.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
Rest	15	30	47	45	96	25	25	100
Work	27	79	30	33	110	20	22	110

Occupation.	Number of subjects.	Number of experiments.	Conjugated phenol÷N×1,000.			Conjugated phenol÷total phenol×100.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
Rest	15	30	22	20	91	47	45	96
Work	27	79	10	11	110	33	33	100

Occupation.	Number of subjects.	Number of experiments.	Total sulphate÷N×1,000.			Inorganic sulphate÷N×1,000.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
Rest	15	30	69	69	100	64	65	102
Work	27	80	61	77	126	54	70	130

Occupation.	Number of subjects.	Number of experiments.	Ethereal sulphate÷N×1,000.			Ethereal sulphate÷total sulphate×100.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
Rest	15	30	4.5	3.7	82	6.5	5.4	83
Work	27	80	7.1	6.8	96	11.6	8.8	76

Table IV, prepared from the average of all our determinations and classified as to whether the subjects were at rest or work, indicates the following points: The total phenol excretion of men at rest averaged slightly less in the afternoon than in the morning. The percentage conjugated was also comparably decreased, thereby making the value of free phenol excreted the same in the afternoon as in the morning, i. e., 25 mg. per gram of nitrogen. We interpret this as indicating that free phenols, to this extent at least, were without sufficient toxic effect to require their conjugation before elimination. Benedict and Theis have reported an average of 4.7 mg. of free phenols per 100 c. c. of blood for 83 specimens, but no conjugated phenols were found. The failure of the organism to conjugate a constant percentage of the phenols present is to our minds, therefore, not as important as its ability to keep the concentration of free phenols in the blood below a certain more or less definite figure. In this connection it should be noted that our observations on men at rest were made on patients recovering from hernia operations and that Benedict and Theis found the blood phenols of hernia patients to average higher than for other pathological conditions. This suggests the explanation of the fact that our average values for resting men were much higher than those for workingmen, but does not necessarily invalidate the use of these men as controls, since we are comparing morning and evening ratios rather than absolute amounts.

The total phenol excretion of men at work was greater in the afternoon than in the morning. The percentage conjugated was the same, but the amount of free phenols increased from 20 to 22 mg. per gram of nitrogen. Comparing these figures with those obtained for men at rest, several points of interest appear. First, with an increase in total phenols of from 30 to 47 mg., the percentage conjugated increased from 33 to 47. This is in keeping with the results of Dubin, who found that an increase in total phenols resulted in an increased conjugation. Second, notwithstanding the great difference between the total phenols, the free phenols of the resting men were not greatly different from those of the workingmen. This is in keeping with our conception of the purpose of detoxication by conjugation, namely, that it is a mechanism to keep the free phenols from reaching a concentration beyond which they are toxic to the organism. Viewing the unchanged percentage conjugation of phenols of men at work, one concludes that muscular effort has had no effect upon this mechanism. Centering our attention upon the slight absolute increase in free phenols, one may tentatively say that there is a tendency for the free phenols to increase, resulting from work, a tendency which, if carried sufficiently far, would reach significant proportions. This, we shall see, actually occurs when the exercise is very severe. It should be mentioned that, as indicated by Table IV, no relationship between the total sulphate and ethereal sulphate excretion is apparent. This might have been anticipated from the fact that the total sulphates were in great excess of the substances requiring conjugation.

The ethereal sulphates are clinically regarded as an index of the extent of intestinal putrefaction. But they, together with the glucuronates, may also be taken as a measure of the degree to which detoxication is effective. We have then to consider the possibilities of combination between the phenols, using the term to include the cresols, and the class of substances represented by indol and skatol on the one hand, and at least two important means of conjugation, sulphuric and glucuronic acids, on the other hand. There are, of course, other substances, such as acetic or propionic acids, which have a share in detoxication; but since their part is a relatively unimportant one, we shall not consider them in this discussion. The possibility exists, and undoubtedly to some extent is always realized, of the following reactions taking place:

(1) Phenols +sulphuric acid =phenylsulphates.
(A) (B) (C)
(2) Phenols +glucuronic acid=phenylglucuronates.
(A) (D) (E)
(3) Indol, etc.+sulphuric acid =indoxylsulphates.
(F) (B) (G)
(4) Indol, etc.+glucuronic acid=indoxylglucuronates.
(F) (D) (H)

TABLE V.—*Conjugated phenols and ethereal sulphates, in milligram equivalents per gram of nitrogen, in the urine of men at rest and at work.*

	Men at rest.		Men at work.	
	a. m.	*p. m.*	*a. m.*	*p. m.*
Conjugated phenol in milligram equivalents	0.23	0.21	0.11	0.12
Ethereal sulphates in milligram equivalents	.14	.12	.22	.21
Difference	+.09	+.09	−.11	−.09

By making the assumption, which, though undoubtedly not wholly correct, is nevertheless useful for purposes of discussion, that the conjugated phenols may be expressed by the formula $C_6H_5OSO_3R$, we have expressed in Table V the conjugated phenols and the ethereal sulphates in milligram equivalents per gram of nitrogen. These figures show that the equivalents of conjugated phenols excreted by men at rest exceeded those of ethereal sulphates by about 0.09. This excess was the same in the afternoon as in the morning, notwithstanding the fact that the total phenols and the conjugated phenols were less in the second period than in the first. In terms of the above equations these facts may be restated as $C+E=C+G+0.09$, or the phenylsulphates exceeded the indoxylsulphates by 0.09 equivalents. Making the same comparisons for men at work, we find that the reverse condition obtains. The ethereal sulphates were 0.11 greater in the morning and 0.09 greater in the afternoon than the conjugated phenols. In other words, for men at work $C_1+E_1+0.11=C_1+G_1$ in the morning, and $C_2+E_2+0.09=C_2+G_2$ in the afternoon.

In presenting these formulæ we have no idea that they represent a complete or entirely accurate picture of the mechanism of detoxication, but we believe that we are justified in introducing them because they permit one to draw certain significant conclusions. One of these is that the men in the hospital either excreted urines poor in the indoxylsulphate group of substances or rich in the phenylglucuronates; whereas in the men chosen for studies on fatigue the tendency to excrete relatively more of the indoxylsulphates was more pronounced. One arrives at this conclusion in the following way: Suppose that an extreme case is assumed for the resting men, in which $C=O$. G would then equal 0.14 and E, 0.23. On the other hand, assume the case where C equals its maximum, 0.14. Then $G=O$, and $E=0.09$. Thus we see that if varying values for phenylsulphates from their minimum to their maximum are assumed, the indoxylsulphates will vary from 0.14 to 0. We believe that in the case of hospital patients the assumption of maximum values for phenylsulphates and minimum values for the phenylglucuronates and indoxylsulphates more nearly represents the true condition than the reverse. This belief is based upon the fact noted by Folin that indican is seldom present in the urine of hospital patients and upon the general teaching that phenylsulphates exceed the phenylglucuronates.

In a similar way it is possible to indicate for the other class of men, the workers, that when $C=O$, $E=0.11$ and $G=0.22$. When C equals its maximum, or 0.11, $E=O$ and $G=0.11$. In other words, the indoxylsulphate group varies from 0.22 to 0.11 as the phenylsulphates pass from their minimum to their maximum values.

Again, it is more plausible to assume the case wherein C approaches its maximum than the reverse. This corresponds to the minimum indoxylsulphate value of 0.11. It is seen then that our results point to a greater excretion of indoxylsulphates in the morning by the men classed as workers than by our controls. The same relationship holds for the afternoon. We interpret this difference as attributable to differences in diet and mode of living, and believe that it indicates that the average worker unduly taxes his protective mechanism by irregular habits and injudicious eating.

TABLE VI.—*Amount of phenol excretion of subjects at rest and at work, arranged according to the arduousness of the work.*

Operation.	Number of subjects.	Number of experiments.	Total phenol÷N×1,000.			Free phenol÷N×1,000.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m/a.m.*
1. Rest	15	30	47	45	96	25	25	100
2. Brazing	1	4	28	32	114	15	15	100
3. Laboratory work	3	4	32	39	122	17	19	112
4. Using 5-pound hammer	2	10	28	28	100	23	23	100
5. General factory work	6	12	31	26	84	17	16	94
6. At cyanide furnace	2	8	28	29	104	18	18	100
7. Foundry, ramming cores	4	13	23	24	104	17	18	106
8. Using 25-pound sledge	1	6	30	34	113	20	23	115
9. At drop forge	1	2	36	31	86	20	18	90
10. Excavating	1	6	37	33	89	24	22	92
11. Race, running 12 miles	4	4	38	61	160	27	38	141

Operation.	Number of subjects.	Number of experiments.	Conjugated phenol÷N×1,000.			Ethereal sulphate+N×1,000.		
			a. m.	*p. m.*	*p.m./a.m.*	*a. m.*	*p. m.*	*p.m./a.m.*
1. Rest	15	30	22	20	91	4.5	3.7	82
2. Brazing	1	4	13	17	131	5.8	4.2	73
3. Laboratory work	3	4	15	20	133	14.8	16.6	112
4. Using 5-pound hammer	2	10	5	5	100	5.3	6.2	117
5. General factory work	6	12	14	10	72	7.5	5.4	72
6. At cyanide furnace	2	8	10	11	110	6.1	8.2	134
7. Foundry, ramming cores	4	13	6	6	100	5.6	4.8	86
8. Using 25-pound sledge	1	6	10	11	110	5.3	4.3	81
9. At drop forge	1	2	16	13	81	10.1	7.2	71
10. Excavating	1	6	13	11	85	6.2	5.4	87
11. Race, running 12 miles	4	4	11	23	210	.8	5.9	738

In order to ascertain whether any progressive relationship existed between the phenols and the arduousness of the work performed, as in the case of the oxidized sulphur excretion, Table VI has been prepared, in which the empirical order of presentation adopted in the previous section has been preserved. An examination of this table shows no regularity of either increase or decrease of total, free, or conjugated phenols during the day in passing down the list of occupations. In fact, only in the case of the men who ran in the 12-mile Marathon race was there a marked change in the quantities eliminated during the period of activity. Here an increase in all quantities was found after the severe exercise. It may be of significance that the subjects in operations 2, 3, 5, 6, and 7 excreted noticeably lower amounts of free phenols than those in operations 4, 8, 9, 10, and 11. If, as we have supposed, the concentration of free phenols is the significant factor in estimating the protective ability of the organism, then, if the organism is functioning efficiently, one would not anticipate an increase in this constituent beyond narrow limits, even though the excretion of total phenols was considerably augmented. Disregarding variations of less than plus or minus 10 per cent, we find that in 8 out of 11 cases this quantity was unchanged; in 2 of the remaining cases there was a rise of 12 and 15 per cent, respectively; whereas in the case of the Marathon runners there was an increase of 41 per cent.

It should be noted that in the latter case the total phenols increased 60 per cent, and the conjugated phenols 110 per cent. This again seems to indicate that the ability of the organism to detoxify phenols increased with an increase in their total concentration. Whether or not the figure of 38 mg. of free phenols excreted represents such a concentration of free phenols in the blood or tissue that it became a factor in the phenomena of fatigue is yet to be determined.

Table VII.—*Total morning phenol excretion, arranged in ascending order of amount and by operation of subjects.*

	Operation number.									
	7	6	2	5	3	4	8	9	10	11
Total phenol	23	28	28	31	32	28	30	36	37	38
Conjugated phenol	6	10	13	14	15	5	10	16	13	11
Ethereal sulphate	5	6	6	8	15	5	5	10	6	6
Free phenol	17	18	15	17	17	23	20	20	24	27

In the first half of Table VII we have arranged in the ascending order of their total phenol excretion in the morning those operations in which the ethereal sulphates, conjugated phenols, and total phenols varied in the same direction. The free phenols were practically constant in these instances. It is significant that these operations, namely, 2, 3, 5, 6, and 7, are the same as those above noted for their low excretion of free phenols. In the second half of the table the remaining operations are studied. These showed an appreciably higher, relatively less constant, free phenol excretion.

Table VIII.—*Comparison of phenol excretion between runners and subjects engaged in an arduous occupation (core rammers).*

	Rammers.		Runners.	
	a. m.	*p. m.*	*a. m.*	*p. m.*
Total phenol in milligram equivalents	0.25	0.26	0.40	0.65
Free phenol in milligram equivalents	.18	.19	.29	.40
Conjugated phenol in milligram equivalents	.07	.07	.11	.25
Ethereal sulphate in milligram equivalents	.17	.15	.02	.18
Difference	.10	.08	.09	.07

Table VIII permits of a comparison between subjects engaged in one of the relatively more arduous occupations, that of ramming molds in a foundry, and men indulging in the excessive exercise of running 12 miles. In the former case there was a slight increase in total phenols, which was reflected in a comparable increase in free phenols. The conjugated phenols were unchanged. The men who ran in the Marathon race showed an increase of 0.25 milligram equivalents of total phenols, which was almost equally distributed between the free and conjugated phenols. The ethereal sulphates increased 0.16 parts, indicating that not only could the 0.14 additional parts of conjugated phenols thus be accounted for, but 0.02 parts remained, which either had replaced a corresponding amount of glucuronic acid or had combined with that equivalent of indol bodies. Because of the fact that these men were in excellent physical condition, having been under the constant care of a physician and coach for several weeks, we believe that bacterial putrefaction in the intestine was at a minimum and that indol bodies were not responsible for this excess of sulphate conjugation. Rather, we think that a portion of the glucuronic and other organic acids previously instrumental in affecting conjugation was oxidized because of the unusual demand made upon the organism for energy, and that it was consequently replaced in part by the sulphates, of which, as we have shown in Part I, there was an increased quantity.

Summary.

1. The concentration of total and neutral sulphur, total, ethereal, and inorganic sulphates, total and combined phenols, and total nitrogen in the morning and afternoon urines of a number of resting individuals and individuals subjected to work of varying degrees of arduousness has been determined.
2. A tendency for a greater excretion of total sulphur per gram of nitrogen at night than in the morning has been noted in both groups of men. The greater part of this increase has been attributed to the sulphur of the food ingested. There seems, however, to be a somewhat greater output in men subjected to the more severe operations.
3. There is practically no increase in the output of sulphate sulphur per gram of nitrogen during the day in men in bed, whereas there is an undoubted increase in men subjected to labor. This increase is larger the more severe the labor.
4. There is a tendency for the proportion of total sulphur (which is eliminated as sulphate) to increase during a day of exercise; and this tendency is much more marked the more severe the exercise.
5. The severity or arduousness of any particular form of labor may be judged by the ratio of the morning to the afternoon sulphate of the urine, providing a sufficient number of determinations have been made upon several individuals.
6. Our experimental results apparently indicate that the ability of the human organism to conjugate the phenol bodies is unchanged by moderate muscular effort.
7. Directing our attention to the absolute excretion of unconjugated phenols, we find that this quantity is increased slightly by moderate work and greatly by strenuous exercise. This suggests that the free phenol excretion may be a factor in severe fatigue.

8. Theoretical considerations indicate that the average worker excretes more indol and allied substances, particularly as sulphates, than men with whom care is taken to maintain regularity of habits and a wise selection of food.

9. Because of the greater dependence of the phenol production and excretion upon the peculiarities of habit and diet of men than upon their muscular activity, no progressive change in quantities or proportion of phenol excretion could be correlated with increasing arduousness of occupation, except in the instance of strenuous exercise.

10. It is thought that simultaneous analytical studies must be made of the phenol and indol groups and the substances with which they are conjugated, notably sulphuric and glucuronic acids, before a positive statement of their relation to fatigue is justified.

TABLE IX.—*Data of individuals grouped by occupations.*

[Data are expressed as grams of nitrogen, sulphur, or phenol per 100 c. c.

GROUP I—REST.

No.	Date.	Time.	Specific gravity.	Total nitrogen.	Total sulphur.	Total sulphate.	Inorganic sulphate.	Total phenol.	Free phenol.
	1917.								
32	Sept. 4	A. M.	1.012	0.487	0.0313	0.0321	0.0224	0.0147	0.0088
B-1		P. M.	1.023	1.419	.1063	.0912	.0847	.0338	.0205
33	Sept. 6	A. M.	1.014	.828	.0659	.0516	.0466	.0265	.0150
B-2		P. M.	1.014	.814	.0640	.0499	.0459	.0276	.0153
34	Sept. 6	A. M.	1.020	1.092	.0722	.0599	.0548	.0234	.0134
B-3		P. M.	1.024	1.548	.1122	.0930	.0878	.0343	.0180
35	Sept. 6	A. M.	1.010	.638	.0255	.0205	.0183	.0136	.0075
B-4		P. M.	1.022	1.200	.0907	.0766	.0708	.0336	.0197
	1918.								
63	Mar. 12	A. M.	1.027	1.513	.1354	.1142	.1103	.0581	.0465
B-5		P. M.	1.022	1.062	.0937	.0787	.0783	.0486	.0350
66	Mar. 15	A. M.	1.025	1.233	.0788	.0687	.0679	.0436	.0264
B-5		P. M.	1.025	1.043	.0886	.0702	.0689	.0344	.0197
64	Mar. 13	A. M.	1.024	1.625	.1120	.0895	.0854	.0765	.0298
B-6		P. M.	1.023	1.818	.1434	.1181	.1137	.0668	.0302
65	Mar. 14	A. M.	1.025	1.338	.2065	.1831	.1793	.0605	.0354
B-7		P. M.	1.022	1.184	.1605	.1440	.1383	.0475	.0222
83	Apr. 11	A. M.	1.022	.532	.0472	.0374	.0346	.0431	.0233
B-8		P. M.	1.024	.913	.0659	.0570	.0462	.0570	.0246
69	Mar. 21	A. M.	1.019	1.879	.2456	.2087	.1989		
B-9		P. M.	1.020	1.590	.2019	.1649	.1562		
70	Mar. 22	A. M.		1.432	.1820	.1549	.1468	.0484	.0276
B-9		P. M.		1.394	.1128	.0887	.0813	.0625	.0337
73	Mar. 27	A. M.	1.022	1.352	.0981	.0863	.0793	.0595	.0364
B-9		P. M.	1.023	1.016	.0757	.0650	.0622	.0417	.0259
74	Mar. 28	A. M.	1.028	1.408	.1009	.0893	.0800	.0514	.0379
B-9		P. M.	1.026	1.359	.0896	.0803	.0734	.0495	.0338
75	Mar. 29	A. M.	1.029	1.555	.1134	.1001	.0916	.0610	.0412
B-9		P. M.	1.031	1.737	.1261	.1115	.1057	.0682	.0500
72	Mar. 26	A. M.	1.021	1.394	.1047	.0946	.0802	.0388	.0239
B-10		P. M.	1.028	1.478	.1336	.1204	.0906	.0503	.0305
76	Mar. 30	A. M.	1.022	1.078	.0818	.0667	.0536	.0457	.0262
B-10		P. M.	1.029	1.195	.1027	.0881	.0835	.0528	.0280
71	Mar. 23	A. M.	1.015	.812	.0734	.0578	.0555	.0366	.0232
B-11		P. M.	1.016	.896	.0758	.0615	.0584	.0430	.0234
87	Apr. 17	A. M.	1.026	1.632	.1087	.0889	.0818	.0790	.0347
B-12		P. M.	1.025	1.188	.0879	.0696	.0643	.0635	.0329
88	Apr. 18	A. M.	1.028	1.348	.0984	.0847	.0752	.0773	.0341
B-12		P. M.	1.027	.949	.0690	.0575	.0536	.0481	.0254
89	Apr. 19	A. M.	1.012	.322	.0342	.0240	.0215	.0389	.0157
B-12		P. M.		.430	.0370	.0257	.0240	.0330	.0159
67	Mar. 18	A. M.	1.014	.490	.0437	.0334	.0302	.0368	.0188
B-13		P. M.	1.025	1.639	.1291	.1043	.1004	.0393	.0298
68	Mar. 19	A. M.	1.011	.427	.0302	.0160	.0158	.0271	.0132
B-13		P. M.		.784	.1011	.0599	.0541	.0807	.0393
85	Apr. 13	A. M.	1.020	.672	.0590	.0464	.0437	.0500	.0220
B-14		P. M.	1.028	.833	.0816	.0611	.0561	.0565	.0264
86	Apr. 16	A. M.	1.023	.728	.0625	.0483	.0461	.0493	.0204

TABLE IX.—*Data of individuals grouped by occupations*—Continued.

GROUP I—REST—Continued.

No.	Date.	Time.	Specific gravity.	Total nitrogen.	Total sulphur.	Total sulphate.	Inorganic sulphate.	Total phenol.	Free phenol.
	1918.								
B-14		P. M.	1.021	0.532	0.0499	0.0358	0.0340	0.0416	0.0159
77	Apr. 3	A. M.	1.021	1.025	.0773	.0648	.0621	.0480	.0223
B-15		P. M.	1.026	1.646	.1519	.1270	.1261	.0664	.0245
78	Apr. 4	A. M.	1.031	1.835	.1770	.1533	.1479	.0426	.0361
B-15		P. M.	1.028	1.380	.0969	.0797	.0755	.0310	.0270
79	Apr. 5	A. M.	1.028	1.429	.1249	.1102	.1051	.0517	.0242
B-15		P. M.	1.031	1.418	.1169	.1014	.0959	.0691	.0308
80	Apr. 6	A. M.	1.030	1.411	.1049	.0848	.0819	.0763	.0332
B-15		P. M.	1.030	1.264	.1489	.1139	.1133	.0591	.0302
81	Apr. 9	A. M.	1.028	1.432	.1051	.0912	.0865	.0581	.0315
B-15		P. M.	1.014	.437	.0457	.0370	.0353	.0311	.0178
82	Apr. 10	A. M.	1.026	1.341	.1121	.0971	.0917	.0536	
B-15		P. M.	1.008	.350	.0265	.0196	.0185	.0156	
84	Apr. 12	A. M.	1.028	1.440	.1119	.0945	.0894	.0581	.0268
B-15		P. M.	1.025	.963	.0815	.0609	.0581	.0510	.0250
GROUP II—BRAZING.									
	1917.								
W1	Oct. 1	A. M.	1.026	1.137	0.1195	0.1057	0.0980	0.0445	0.0235
F-1		P. M.	1.030	1.436	.1700	.1520	.1480	.0673	.0396
W2	Oct. 2	A. M.	1.022	1.193	.1010	.0827	.0782	.0357	.0181
F-1		P. M.	1.027	1.475	.1571	.1360	.1271	.0520	.0249
W3	Oct. 3	A. M.	1.034	2.466	.2271	.2029	.1838	.0622	.0355
F-1		P. M.	1.033	2.419	.1781	.1533	.1462	.0553	.0254
W4	Oct. 4	A. M.	1.026	1.373	.0898	.0769	.0702	.0300	.0198
F-1		P. M.	1.033	1.859	.1755	.1524	.1434	.0430	.0246
GROUP III—LABORATORY WORK.									
W63	June 12	A. M.		0.919	0.0548	0.0508	0.0426		
E. L. S		P. M.		.744	.0556	.0480	.0424		
W64	June 21	A. M.	1.020	.818	.0564	.0508	.0448		
E. L. S		P. M.	1.024	1.018	.0976	.0849	.0764		
W65	July 2	A. M.	1.027	1.572	.1290	.1080	.0949		
E. L. S		P. M.	1.029	1.656	.1432		.1092		
W66	July 16	A. M.	1.024	1.375	.1174	.1000	.0800		
E. L. S		P. M.	1.023	1.183	.1054	.0922	.0853		
W67	Aug. 15	A. M.	1.007	.394	.0234	.0199	.0173	0.0108	0.0055
E. L. S		P. M.	1.025	1.074	.0660	.0561	.0477	.0379	.0409
W68	July 2	A. M.	1.022	1.620	.1273	.1090	.1002		
F. W. K		P. M.	1.022	1.442	.1355	.1170	.1095		
W69	July 5	A. M.	1.018	1.320	.0974	.0802	.0734		
F. W. K		P. M.	1.025	1.494	.1480	.1269	.1142		
W70	July 5	A. M.	1.016	.840	.0595	.0465	.0410		
F. S. L		P. M.	1.030	1.382	.1148	.0944	.0864		
W71	Aug. 31	A. M.	1.022	.810	.0651	.0499	.0382	.0337	.0176
E. C. B		P. M.	1.021	.701	.0554	.0396	.0337	.0277	.0129
GROUP IV—LABORATORY WORK AND 10-MILE WALK.									
W72	July 17	A. M.	1.023	1.305	0.0961	0.0818	0.0736		
E. L. S		P. M.	1.025	1.217	.1062	.0943	.0850		
W73	July 17	A. M.	1.022	1.134	.0705	.0556			
F. S. L		P. M.	1.030	1.621	.1078	.0995	.0921		
GROUP V—USING 5-POUND HAMMER.									
	1917.								
W41	Nov. 26	A. M.	1.028	1.045	0.0977	0.0841	0.0818	0.0179	0.0149
F-2		P. M.	1.032	1.304	.1722	.1585	.1530	.0249	.0264
W42	Nov. 27	A. M.	1.026	1.107	.0931	.0773	.0766	.0115	.0158
F-2		P. M.	1.030	1.869	.1791	.1593	.1467	.0168	.0221
W43	Nov. 28	A. M.	1.027	1.345	.1041	.0921	.0855	.0390	.0331
F-2		P. M.	1.030	1.506	.1622	.1486	.1391	.0607	.0481
W44	Dec. 1	A. M.	1.021	.699	.0505	.0401	.0359	.0248	.0187
F-3		P. M.	1.018	.887	.0845	.0654	.0578	.0246	.0258
W45	Dec. 3	A. M.	1.026	1.019	.0822	.0683	.0615	.0395	.0286
F-3		P. M.	1.016	.609	.0498	.0407	.0366	.0201	.0151
W46	Dec. 4	A. M.	1.026	.912	.0903	.0752	.0661	.0268	.0328
F-3		P. M.	1.029	.833	.1110	.0963	.0940	.0288	.0172

TABLE IX.—*Data of individuals grouped by occupations*—Continued.

GROUP V—USING 5-POUND HAMMER—Continued.

No.	Date.	Time.	Specific gravity.	Total nitrogen.	Total sulphur.	Total sulphate.	Inorganic sulphate.	Total phenol.	Free phenol.
W47	1917. Dec. 5	A. M.	1.029	0.802	0.0874	0.0764	0.0721	0.0316	0.0203
F-3		P. M.	1.025	.939	.0934	.0770	.0727	.0287	.0223
W48	Dec. 6	A. M.	1.025	.692	.0506	.0400	.0374	.0202	.0140
F-3		P. M.	1.023	.698	.0583	.0464	.0412	.0282	.0229
W49	Dec. 7	A. M.	1.017	.588	.0442	.0272	.0248	.0151	.0115
F-3		P. M.	1.023	.997	.0806	.0700	.0645	.0275	.0216
W50	Dec. 8	A. M.	1.025	1.044	.0576	.0471	.0437	.0224	.0195
F-3		P. M.	1.025	1.103	.0848	.0714	.0674	.0239	.0157
GROUP VI—GENERAL FACTORY WORK.'									
W78	Aug. 15	A. M.		1.052	0.0645	0.0512	0.0403	0.0307	0.0187
S-1		P. M.		1.059	.1024	.0860	0802	.0325	.0195
W79	Aug. 22	A. M.		1.445	.0864	.0711	.0641	.0331	.0172
S-1		P. M.		1.249	.1075	.0910	.0855	.0370	.0197
W80	Aug. 15	A. M.		1.793	.1262	.1116	.0927	.0376	.0209
S-2		P. M.		1.747	.1430	.1246	.1149	.0355	.0250
W81	Aug. 22	A. M.		2.051	.1312	.1056	.0962	.0345	.0225
S-2		P. M.		1.793	.1387	.1179	.1112	.0463	.0212
W82	Aug. 15	A. M.		.826	.0719	.0586	.0536	.0228	.0138
S-3		P. M.		1.228	.1114	.0957	.0923	.0251	.0144
W83	Aug. 22	A. M.		1.464	.1184	.0964	.0845	.0500	.0236
S-4		P. M.		1.354	.1209	.0967	.0844	.0417	.0236
W84	Aug. 22	A. M.		.799	.0571	.0466	.0418	.0315	.0202
S-5		P. M.		1.179	.0942	.0802	.0747	.0345	0219
GROUP VII—CYANIDE FURNACE.									
W12	Oct. 22	A. M.	1.031	1.603	0.1539	0.1332	0.1192	0.0436	0.0272
F-4		P. M.	1.036	1.683	.1631	.1455	.1281	.0500	.0286
W13	Oct. 23	A. M.	1.031	1.609	.1080	.0919	.0792	.0446	.0268
F-4		P. M.	1.033	1.448	.1276	.1068	.0961	.0422	.0243
W14	Oct. 24	A. M	1.031	1.595	.1327	.1067	.1003	.0480	.0328
F-4		P. M.	1.029	1.220	.1196	.1038	.0938	.0414	.0224
W15	Oct. 25	A. M.	1.029	1.129	.0976	.0815	.0747	.0355	.0214
F-4		P. M.	1.034	1.296	.1290	.1119	.0966	.0343	.0207
W17	Nov. 1	A. M.	1.028	1.737	.1094	.0954	.0809	.0403	.0212
F-4		P. M.	1.035	1.534	.1430	.1227	.1053	.0478	.0281
W25	Nov. 6	A. M.	1.028	1.034	.0677	.0527	.0502	.0290	.0181
F-4		P. M.	1.030	1.263	.0962	.0809	.0763	.0358	.0219
W32	Nov. 15	A. M.	1.038	2.070	.1855	.1649	.1507	.0481	.0312
F-4		P. M.	1.030	1.192	.0929	.0803	.0743	.0284	.0194
W40	Nov. 26	A. M.	1.029	.637	.0408	.0300	.0261	.0193	.0142
F-5		P. M.	1.027	1.275	.1502	.1312	.1179	.0334	.0316
GROUP VIII—RAMMING CORES.									
W21	Nov. 5	A. M.	1.030	1.362	0.0891	0.0736	0.0674	0.0353	0.0206
F-6		P. M.	1.033	1.540	.1406	.1202	.1125	.0408	.0272
W22	Nov. 6	A. M.	1.029	1.611	.0830	.0647	.0615	.0343	.0227
F-6		P. M.	1.027	1.481	.1215	.1064	.1018	.0572	.0372
W23	Nov. 7	A. M.	1.028	1.383	.0858	.0735	.0684	.0369	.0227
F-6		P. M.	1.028	1.513	.1193	.1024	.0991	.0503	.0310
W24	Nov. 8	A. M.	1.028	2.079	.1277	.1083	.1016	.0536	.0328
F-6		P. M.	1.030	1.471	.1013	.0916	.0823	.0421	.0307
W29	Nov. 15	A. M.	1.021	.609	.0375	.0298	.0275	.0274	.0149
F-7		P. M.	1.027	1.023	.0858	.0741	.0691	.0281	.0204
W30	Nov. 16	A. M.	1.028	1.200	.0747	.0608	.0540	.0292	.0214
F-7		P. M.	1.027	.857	.0679	.0559	.0422	.0247	.0194
W31	Nov. 17	A. M.	1.007	.106	.0079	.0047	.0032	.0125	.0089
F-7		P. M.	1.026	.893	.0618	.0482	.0432	.0225	.0180
W33	Nov. 19	A. M.	1.021	.557	.0465	.0374	.0327	.0167	.0140
F-7		P. M.	1.028	.958	.0827	.0677	.0603	.0327	.0243
W34	Nov. 20	A. M.	1.022	.657	.0507	.0453	.0363	.0202	.0160
F-7		P. M.	1.028	1.135	.1001	.0836	.0794	.0299	.0255
W35	Nov. 21	A. M.	1.025	1.016	.0619	.0509	.0439	.0231	.0192
F-7		P. M.	1.029	1.149	.0948	.0848	.0749	.0233	.0211
W36	Nov. 22	A. M.	1.017	.532	.0322	.0268	.0219	.0105	.0103
F-7		P. M.	1.026	.922	.0657	.0555	.0514	.0219	.0162
W37	Nov. 21	A. M.	1.024	.634	.0448	.0321	.0304	.0135	.0116
F-8		P. M.	1.033	1.357	.1076	.0918	.0872	.0260	.0222
W39	Nov. 23	A. M.	1.028	1.149	.0551	.0493	.0455	.0198	.0193
F-8		P. M.	1.033	1.459	.1254	.1013	.0926	.0328	.0303

TABLE IX.—*Data of individuals grouped by occupations*—Continued.

GROUP IX—USING 25-POUND SLEDGE.

No.	Date.	Time.	Specific gravity.	Total nitrogen.	Total sulphur.	Total sulphate.	Inorganic sulphate.	Total phenol.	Free phenol.
W51	1917. Dec. 10	A. M.	1.023	1.604	0.1084	0.0800	0.0740	0.0418	0.0252
F-9		P. M.	1.028	1.191	.0978	.0863	.0815	.0273	.0224
W53	Dec. 12	A. M.	1.020	1.026	.0615	.0500	.0435	.0212	.0148
F-9		P. M.	1.027	1.240	.0993	.0827	.0789	.0400	.0229
W54	Dec. 13	A. M.	1.013	.539	.0295	.0236	.0217	.0178	.0100
F-9		P. M.	1.027	1.320	.0997	.0870	.0801	.0357	.0243
W55	Dec. 14	A. M.	1.013	.444	.0279	.0226	.0204	.0146	.0096
F-9		P. M.	1.025	.913	.0796	.0686	.0632	.0185	.0157
W56	Dec. 15	A. M.	1.013	.252	.0195	.0126	.0105	.0102	.0076
F-9		P. M.	1.024	.731	.0583	.0448	.0424	.0361	.0179

GROUP X—DROP FORGE.

W9	Oct. 16	A. M.	1.020	0.808	0.0485	0.0374	0.0323	0.0315	0.0140
F-10		P. M.	1.023	1.105	.0958	.0773	.0713	.0318	.0191
W10	Oct. 18	A. M.	1.023	.867	.0788	.0610	.0489	.0289	.0197
F-10		P. M.	1.033	1.614	.2096	.1793	.1646	.0532	.0310

GROUP XI—EXCAVATING.

W57	Dec. 17	A. M.	1.019	0.731	0.0372	0.0293	0.0239	0.0392	0.0278
F-11		P. M.	1.028	1.313	.1548	.1366	.1247	.0556	.0353
W58	Dec. 18	A. M.	1.029	1.663	.0985	.0809	.0698	.0630	.0323
F-11		P. M.	1.033	1.586	.1379	.1250	.1194	.0510	.0327
W59	Dec. 19	A. M.	1.024	1.243	.0741	.0607	.0528	.0482	.0292
F-11		P. M.	1.032	1.604	.1446	.1300	.1210	.0454	.0357
W60	Dec. 20	A. M.	1.012	.490	.0251	.0196	.0169	.0185	.0135
F-11		P. M.	1.028	1.150	.1054	.0938	.0889	.0321	.0231
W61	Dec. 21	A. M.	1.028	1.635	.0807	.0679	.0583	.0372	.0280
F-11		P. M.	1.029	1.233	.1115	.0958	.0899	.0364	.0276
W62	Dec. 22	A. M.	1.028	1.410	.0887	.0649	.0566	.0437	.0291
F-11		P. M.	1.032	1.370	.1045	.0920	.0849	.0528	.0304

GROUP XII—RUNNING 12 MILES.

M-1	1918. May 4	A. M.	1.027	1.034	0.0692	0.0563	0.0543	0.0369	0.0211
		P. M.	1.033	1.284	.2008	.1665	.1568	.0658	.0375
M-2	May 4	A. M.	1.021	.710	....	....	....	.0278	.0274
		P. M.	....	.742	....	....	....	.0658	.0421
M-3	May 4	A. M.	1.022	1.116	.1050	.0647	.0646	.0327	.0222
		P. M.	1.034	1.191	.2120	.1651	.1621	.0577	.0421
M-4	May 4	A. M.	1.029	.630	.0800	.0493	.0492	.0294	.0179
		P. M.	1.024	.826	.1234	.1006	.0942	.0462	.0272

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